PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G06K 7/08, 7/10

A1

(11) International Publication Number: WO 99/33017

(43) International Publication Date: 1 July 1999 (01.07.99)

(21) International Application Number: PCT/GB98/03848

(22) International Filing Date: 21 December 1998 (21.12.98)

(30) Priority Data:
9727042.5 22 December 1997 (22.12.97) GB

(71) Applicant *(for all designated States except US)*: ADVANCED TECHNOLOGY COMMUNICATIONS LIMITED [GB/GB]; 14 Tonbridge Chambers, Pembury Road, Tonbridge, Kent TN9 2HZ (GB).

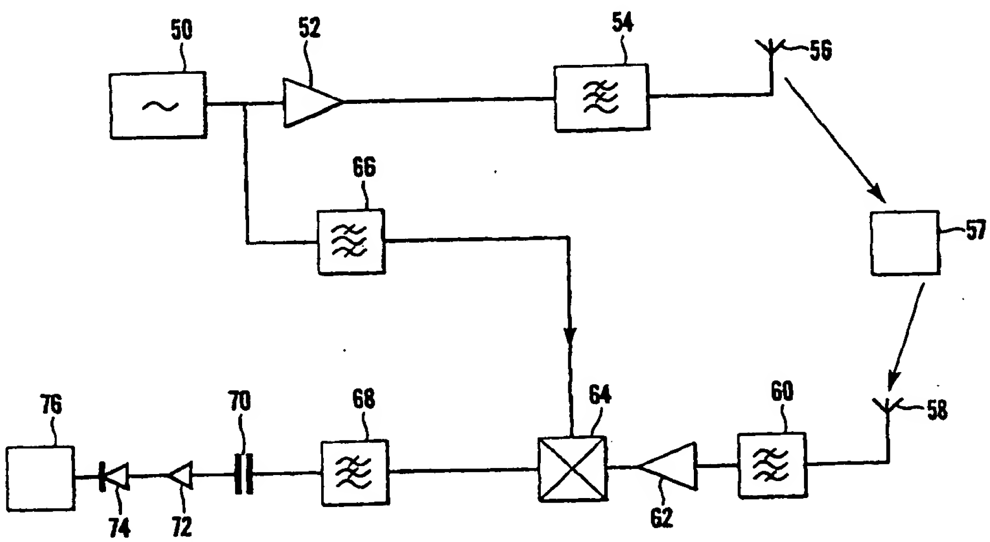
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HADFIELD, George [GB/GB]; "Clovelly", 46 Thorpe Avenue, Tonbridge, Kent TN10 4SD (GB).

(74) Agent: SANDERS, Peter, Colin, Christopher; Brookes & Martin, High Holborn House, 52–54 High Holborn, London WC1V 6SE (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: TAG AND DETECTION SYSTEM



(57) Abstract

An electronic tag is described which, when stimulated by radiation at a first frequency, responds by producing radiation at a second frequency different from the first. Preferably the tag comprises a non–linear element and a tuned circuit and the radiation is radio–frequency electromagnetic radiation. The second frequency is preferably an integer multiple of the first frequency. Also described are a homodyne radar to detect an electronic tag comprising a non–linear element, the radar transmitting at a first frequency and responding to a signal received at a second frequency different to the first frequency; and a tag detection gateway comprising a directional antenna. An electronic tagging system comprising: an electronic tag and a homodyne radar to detect the tag. A method for detecting an electronic tag comprises providing a tag including a non–linear element, providing r.f. radiation at a first frequency to the tag, and detecting r.f. radiation at a second frequency, different to the first, from the tag.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

TAG AND DETECTION SYSTEM

This invention relates to an improved electronic tagging device and a corresponding detection system.

An electronic tag will generally include at least one electronic component capable of reacting with a field of radiation, particularly electromagnetic radiation, and means for attaching the component or components to an object being tagged, such that an electrical signal is produced when the object is brought into the radiation field. For example, the electronic component may be carried on a substrate which is adhesively bonded, clipped or otherwise secured or releasably secured to the object.

Electronic tags find a variety of applications - for example they are commonly used in shops where they are attached to goods on sale so that unauthorised removal of an item from the shop can be detected. They also find application in warehouses, for example for identifying or tracking movement of goods, and in secure areas, to detect unauthorised movement of people or property into or out of the area. The tag and detection system to be described is particularly suitable for use in shops but it will be apparent that many other applications are also possible.

Tags to be attached to goods for sale must meet a number of requirements, the details of which depend upon the particular application. Tags for say, food items, publications or compact disks must be unobtrusive and are commonly almost flat so

that they can be concealed under a bar code or price tag. Larger tags may be acceptable for clothing. It is a common requirement for tags that they be inexpensive - some current tags can be manufactured for less than 0.01 pounds each.

A conventional tag is illustrated in Figure 1. It consists of a flat inductor (L) and a central capacitor (C) forming an LC tuned circuit. Manufacturing tolerances and variations in the properties of the materials used in the tag's construction (for example, foil resistivity and insulator dielectric constant) mean that the circuit's resonant frequency is broad and imprecisely defined. The tag is detected by measuring the disturbance it causes when brought into an RF (radio frequency) electromagnetic field, typically at around 10 MHz. The detection of such tags is generally accompanied by a high false alarm rate (FAR) since many other items such as pushchairs, electrical wiring and other metal structures can also disturb the RF field. Attempts have been made to circumvent these problems by physically constraining the detection space, for example, making customers walk through narrow gates. However this is undesirable because it can reduce a shop's custom and sales and is not always practical.

The present invention seeks to alleviate the problems of conventional tags by providing a tag with a potentially superior detection range and a potentially lower false alarm rate. According to the present invention there is provided an electronic tag which, when stimulated by radiation at a first frequency, responds by producing radiation at a second frequency different from the first. Since the tag emits radiation

at a frequency which is different from that used to illuminate it the false alarm rate is potentially substantially reduced. Although many objects in the tag's environment will reflect radiation at the frequency of illumination, only the tag will re-radiate at a different frequency, therefore significantly improving the signal to noise ratio, since at the second frequency there will little or no clutter.

The illuminating radiation is preferably RF radiation and the second frequency may advantageously be an integer multiple of the first, preferably twice the first frequency. Frequencies at integer multiples of the fundamental can be generated by including a non-linear element in the tag to generate second, third or higher harmonic distortion. The tag will preferably include a tuned circuit, although the response of the antenna may itself provide sufficient selectivity. The tuned circuit may be constructed from discrete components or may be a lumped element. The non-linear element may be a semiconductor junction; preferably it comprises a Schottky diode.

The tag may further comprise means to modulate the radiation emitted at the second frequency, for example an oscillator. Alternatively (or additionally) a data store can be included within the tag and the returned frequency can be modulated with stored data to provide additional information about the tagged object. The tag may be active or passive; in this specification, "passive" is used to denote "lacking an internal power source". In other words, the tag may be powered by the illuminating radiation or may have its own internal power source.

The tag may operate at relatively low frequencies, for example less than 20 megahertz, and couple into the magnetic field of the illuminating radiation, or it may operate at relatively high frequencies, for example greater than 100 megahertz, and couple into the electric field of the illuminating radiation.

The tag may be constructed so that it has a relatively flat, planar form. A tag with the form of a lamina is advantageous for application to shop goods.

According to a second aspect of the invention, there is provided a homodyne radar for detecting the tag, the radar transmitting a first frequency and responding to a signal received at a second frequency different to the first. The second frequency may be an integer multiple, preferable two, of the first frequency. The radar preferably includes an oscillator operating at the first frequency to provide a transmit signal, a second harmonic of the oscillator being mixed with the received signal. Preferably the signals are mixed in a mixer, the output of which is coupled to a low pass filter, which is AC coupled to a detector and circuitry to provide an output to indicate detection of the tag.

According to a third aspect of the invention there is provided a tag detection gate including a patch antenna having a conductive patch with longitudinal and transverse axes of different lengths. The gate may include transmit and receive patch antenna arrays. A tag detection gateway may comprise two opposing gates, one of which is a tag detection gate, and the other of which comprises an RF antenna or RF

reflector.

According to a fourth aspect of the invention there is provided an electronic tagging system comprising an electronic tag, a homodyne radar to detect the tag, and, optionally, a gateway as described above. The homodyne radar preferably has a low pass filter with a bandwidth at least 100 times less than the first frequency. The transmit frequency may be varied by, for example, sweeping to allow for a variation in the tags' resonant frequencies due to manufacturing and material tolerances/variations. To maintain sensitivity but reduce average transmitted power, the radar output may be pulsed, for example with a 1:10 mark:space ratio and synchronous detection may then be used. A reduction in average transmitted power has potential safety advantages, and the reduced power consumption provides a useful increase in battery life in portable, battery-powered equipment.

According to a fifth aspect of the invention there is provided a method for detecting an electronic tag comprising providing a tag including a non-linear element, providing RF radiation at a first frequency to the tag, and detecting RF radiation at a second frequency, different to the first, from the tag. The steps of providing and detecting RF radiation may use a homodyne radar and the RF radiation at the first frequency may be swept over a range of frequencies and/or pulsed. The step of detecting may comprise synchronous detection of the radiation from the tag with the pulsed transmissions at the first frequency. The non-linear element is preferably a semiconductor junction and may be a Schottky diode; the second frequency may be

an integer multiple, preferably two, of the first frequency. The tag is preferably a passive tag.

In order to promote a fuller understanding of the above and other aspects of the invention, some embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a conventional electronic tag;

Figure 2 shows tags embodying aspects of the invention;

Figure 3 shows further tags, embodying aspects the present invention, which provide a modulated return signal;

Figure 4 shows a block diagram of a homodyne radar, suitable for detecting tags, embodying aspects of the present invention;

Figure 5 shows a gateway embodying aspects of the present invention; and

Figure 6 shows a patch antenna embodying aspects of the present invention.

Figure 2A shows a preferred circuit for an electronic tag when operating at relatively low frequencies. The tag provides a radio frequency electromagnetic radiation return at a different frequency from the frequency of the RF electromagnetic radiation illuminating it. Inductor 10 and capacitor 12 form a tuned circuit with component values chosen for resonance at a first frequency (f_0). For example values of 7.5 μH and 20pF provide a resonant frequency of 13MHz whilst 10μH and 39 pF resonate at 8MHz. Inductor 10 may double as a magnetic loop antenna to couple

energy at the illuminating frequency f_0 into the tag. Although inductor 10 and capacitor 12 are drawn as separate circuit elements, they may be combined into a single resonant element. For example, a suitable choice of substrate (such as a material with a relatively high dielectric constant) can be used to provide distributed capacitance.

The non-linear element in the circuit of Figure 2A is diode 14, although any non-linear device may be used in its place. Providing that the voltage induced across inductor 10 by the illuminating RF field is sufficient to cause diode 14 to start to conduct, the voltage across inductor 10 and the currents flowing into and out of capacitor 12 will be non-linear - that is they will not be a constant multiple of the external impressed field. The illuminating radiation is at a single frequency and hence close to purely sinusoidal. The presence of diode 14 will result in a squaring of the sinusoidal wave shape. If the non-linear element were such that this squaring was symmetrical mainly odd harmonics would be produced. However, because a diode is used, one half cycle of the sinusoid is effectively attenuated or truncated, which results in the generation of even harmonics, especially the second harmonic. The tag therefore effectively re-radiates at the second harmonic ($2f_0$) of the illuminating frequency. Alternatively the process can be thought of as a modification or distortion of the illuminating field giving rise to detectable second and higher harmonic distortion. From the preceding discussion it can be seen that a variety of different components could be used to provide a suitable non-linearity.

Figure 2B shows an alternative configuration of the tuned circuit 10, 12 and diode 14. Figure 2C shows a circuit corresponding to Figure 2A, but with transistor 16 as the non-linear element. In general, the non-linear element may be a semi-conductor junction or it may be some other type of non-linear load such as, for example, an oscillator, as described below with reference to Figure 3A.

Figure 2D shows a tag which couples electrically into the illuminating radiation by means of dipole 17. There is no tuned circuit *per se* in this tag; instead the response of dipole 17 is used to provide selectivity which, as is known by those skilled in the art, may again be varied by varying the dipole's dimensions and the substrate (if any) upon which it is mounted.

Figure 2E shows an active rather than a passive tag with power supply 20 and resistor 22 being used to bias diode 14 into conduction. This obviates the need for a threshold voltage of the diode to be induced across inductor 10 and therefore provides potentially increased sensitivity. Capacitor 18 blocks the DC path through the coil.

It can be seen that it is beneficial to use a diode which begins to conduct at a relatively low forward voltage. Furthermore when high frequency illumination is used a relatively fast switching diode is desirable. Both these desiderata suggest that a Schottky diode is preferable for diode 14.

The skilled person will understand that the choice of whether to use a dipole or magnetic loop antenna will depend upon the operating frequency of the tag. At lower frequencies (say a few megahertz) a magnetic loop antenna will be preferred for its smaller size (for a flat coil typically 2 to 3 cm diameter); at higher frequencies (say above 100 megahertz) a dipole will be preferable. The skilled person will appreciate that the total length of the dipole as illustrated in Figure 2D should be approximately half a wave length of the illuminating radiation ($\lambda/2$). At 1GHz a 15 cm dipole is required, although much smaller lengths can be used at the expense of reduced coupling efficiency. For example, a 1 to 2 cm or smaller antenna is sufficient with a sensitive tag detection device. However, it can be appreciated that the higher the frequency of illuminating radiation, the potentially smaller and more efficient the tag (at least at high frequencies where electrical coupling is used). Depending upon the requirements of the intended application, anisotropy of the antenna response may or may not be a desirable characteristic. If a more isotropic response is required, two or more antennas can be used at differing orientations to "smooth out" the response. These may be associated with separate tuned circuits or a common tuned circuit. It will be appreciated that the physical size of a tag will normally be determined largely by the size of its antenna.

As outlined above, an important advantage of the described tags is that they provide a return at a different frequency from that at which they are illuminated, and hence differentiate from reflective clutter. Further differentiation may be provided by the homodyne radar, as described below, which is configured to detect a <u>change</u>

in the response at the return frequency rather than simply detecting signal level at this frequency. Although the present tags are described as operating at radio frequencies with electromagnetic radiation, the same concept may be applied at other frequencies and using other types of radiation. For example, an acoustic tag could be constructed to receive a signal at a fundamental frequency and re-radiate at a different frequency such as the second or third harmonic. For example, a non-linear acoustic device could be stimulated at ultrasonic frequencies and an ultrasonic second or higher harmonic could be detected. Furthermore, the stimulating and emitted radiations could be of different types. For example, the illuminating RF field could stimulate ultrasonic (or other frequency) acoustic radiation from the tag.

A suitable physical configuration for the tag can be achieved using surface - mount construction techniques. The inductor can be formed from a coil of wire or a printed track; the capacitor can be constructed from two layers of metallization separated by dielectric. The diode can be a conventional leaded component, a surface mount component or a naked die component; the whole can be constructed on a PCB or other substrate or on a flexible membrane. The components may be mounted on a carrier attached to the object to be tagged or embedded in the tagged object.

Figure 3 shows a group of tags based upon the same principles as those of Figure 2 but with the additional capability of modulating the return signal. Although all are drawn as "passive" (as defined earlier) tags, it will be apparent that these tags could be provided with a separate power source such as an internal battery, so

reducing the power requirements of the illuminating signal.

Figure 3A shows a tag corresponding broadly to that of Figure 2A, but additionally including an oscillator 24. The oscillator is powered by energy received from a remote transmitter which is part of the tag detection system and can be a single transistor circuit operating at, for example, 1MHz. The oscillator 24 modulates the second (or other) harmonic return from the tag simply by being present as a load across the tuned circuit - there is no requirement for a connection to be made to the oscillator output. The purpose of modulating the return is to provide an additional improvement factor to the tag detection signal to noise ratio. Not only can the second harmonic return be filtered out or otherwise separated from the fundamental frequency but an additional narrow band filter can be employed to look for a signal at the frequency of oscillator 24 to provide a further significant reduction in background clutter (it is known that certain metal-to-metal junctions can generate spurious second harmonic returns).

Figure 3B shows an alternative method of modulating the second or higher harmonic reflection. Circuit element 34 is powered by the illuminating radiation by means of diode 28 and a smoothing circuit comprising resistor 30 and capacitor 32. Element 34 may be a low power microprocessor or a suitable memory device, configured to provide a serial data output on line 36. This data is used to control a chopping element, shown as bipolar transistor 26, which is connected across the tuned circuit including inductor 10 and capacitor 12, effectively acting as a switch in order

to modulate the second harmonic radiation. It will be apparent to the skilled person that alternative devices can be used to provide the chopping function. Figure 3C shows an alternative configuration with the chopping element in series with, rather than across the tuned circuit.

One advantageous means of detecting these tags will now be described with regard to Figure 4, which shows a homodyne radar. Oscillator 50 generates a signal at the frequency, f_0, of the illuminating radiation. Typically the output from oscillator 50 will also comprise low levels of harmonics, which in this application is advantageous. The output from oscillator 50 is fed to power amplifier 52 which drives transmit antenna 56 with sufficient power to illuminate and detect a return signal from a tag over the required detection space. For a 20 ft range at 900 MHz an output power of 2 watts is suggested. When transmitting at this frequency antenna 56 can be a dipole, yagi or patch array. Alternatively a transmit frequency of 9 MHz can be used, when antenna 56 is a wire loop aerial.

The purpose of low pass filter 54 is to reduce the level of second harmonic in the transmitted output. Although shown following the power amplifier 52, it could equally well precede it. Typically the output level of the second harmonic at the antenna is $>>80$ dB below the fundamental although, as discussed below, some coupling of second harmonics between transmit and receive sections of the radar can be tolerated.

The output of oscillator 50 is also provided to band pass filter 66. This rejects the fundamental and passes the second harmonic component of the oscillator output and can therefore have a relatively broad pass band centred at $2f_0$. The output of band pass filter 66 is fed to mixer 64, which will normally be a double balanced mixer. A second input to mixer 64 is provided by the signal received at receive antenna 58, which is coupled to the mixer via band pass filter 60 and front end amplifier 62. Depending upon the received frequency (in the above examples, 1.8 GHz and 18 MHz) the same choices are available for the receive antenna 58 as for transmit antenna 56. When the system is used at a gateway or supermarket check point, a patch antenna is useful as it provides less than 180° coverage. Band pass filter 60 is again centred at $2f_0$ and again can have a relatively broad pass band; front end amplifier 62 will typically provide around 20db of gain.

It can be seen that the homodyne radar is mixing two frequencies which are both derived from a single source and which are therefore at least frequency-locked and will often will be phased-locked. The common source is oscillator 50 which provides a second harmonic directly to mixer 64 and indirectly to the mixer via transmit antenna 56, tag 57 and receive antenna 58. The consequence of this is that the output of mixer 64, if tag 57 is stationary, will consist purely of a DC level. This is independent of the actual frequency of oscillator 50 since both mixed signals are derived from the same source. The mixer output can therefore be processed using a low pass filter with a very low cut-off frequency and this is effectively reflected back through the mixer to provide an effect equivalent to the application to the

received signal of a band pass filter of corresponding bandwidth to that of the low-pass filter. Effectively the received signal is filtered using an extremely narrow band pass filter, thus providing highly selective detection of the return signal. The homodyne radar design achieves this without the requirement for a correspondingly stable oscillator or the need to physically construct a narrow band pass filter, which is difficult. The detection signal to noise ratio can be improved by a factor of 10^3 or more using this technique, without the need for additional transmit power (with consequent advantages in size, power consumption, safety and reliability). The output of mixer 64 is coupled to low pass filter 68 which can have a cut off frequency of less than 10 MHz at $2f_0 = 1.8$ GHz, or less than 100 Kz at $2f_0 = 18$ MHz. Although the radar has been described as mixing signals at f_0 and $2f_0$, some of the benefits of the device's effectively narrow bandwidth (selectivity and hence a reduction in sensitivity to r.f. interference) can also be realised when receiving at f_0 (and hence mixing signals with the same frequency).

The design does not require isolation of the transmit and receive antennas but allows for some direct antenna-to-antenna coupling. The result of such coupling will be a low, steady DC level at the output of mixer 64. This is removed by AC coupling 70 which can, in the simplest case, be a capacitor. The result is that the radar is arranged to detect a change in received second harmonic rather than an absolute level of second harmonic signal - this provides an additional sensitivity increase. The use of AC coupling 70 means that the radar effectively acts as a Doppler frequency detector and detects movement of a tag into or out of the

responsive field of the system rather than the presence or absence of a tag *per se*.

The AC output is amplified by gain stage 72 (typically 50dB) and detected by rectifier 74 which can be, for example, an operational amplifier full wave bridge rectifier. The output of detector 74 is coupled to output detection circuit 76 which can comprise, for example, a comparator to respond to a threshold level of the detected signal and provide a "tag detected" output. The output provided by detection circuit 76 can be a visual or audible alert or a signal which can be logged by a data logger to record time, date and tag information. Many other variants will also occur to the skilled person.

The described embodiment of the homodyne radar responds to a signal at the second harmonic of the oscillator but the advantage of using the homodyne radar as a detector can also be achieved at other received frequencies, providing the "direct" signal to the mixer and the signal received via the tag are derived from the same oscillator. Higher harmonics of oscillator 50 could be employed; alternatively a phase locked loop and divider could be employed in a conventional manner to derive fractional multiples of f_0 from oscillator 50 in a conventional manner. For example, a phase locked loop (PLL) with input $f_0/2$ and a divide by three circuit in the loop will provide a PLL voltage controlled oscillator output of $1\frac{1}{2}\ f_0$. In general, any integer ratio m/n of f_0 can be obtained. Alternatively oscillator 50 could be a digital synthesizer generating two different frequencies. It will be apparent to the skilled person that since the advantage of the tags previously described lies in their re-

radiation at a frequency different from that at which they are illuminated, the use of any frequency other than f_0 for reception will provide an improved signal to noise ratio.

A number of variations on the basic design are possible. For example, to take account of variations in tags' resonant frequencies, the homodyne radar oscillator could be swept over a range of frequencies. The limits of the range would be determined by the manufacturing tolerances of the tags themselves, and, if required, could be 20% or more of f_0. To provide this function, oscillator 50 may be replaced by a ramp generator driving a voltage controlled oscillator. The form of the frequency radiation is determined by the output waveshape of the ramp generator - a sawtooth waveshape will provide a linear frequency variation.

The transmitter output could be pulsed to reduce the average power output whilst retaining a high peak power to the tags. For example, a one to ten mark space ratio could reduce the average transmitted power from say 2 watts to 0.2 watts. A pulsed transmitter output can be provided by controlling power amplifier 52, for example by pulsing its power supply. Alternatively the input to the power amplifier can be pulsed; it is preferable to keep oscillator 50 running for stability. If synchronous detection were employed, by gating the output of the mixer 64, or at a later stage, for example after detector 74, tag detection circuitry could be arranged to be active during transmission but not otherwise. For example, a sample/hold circuit comprising a CMOS gate and capacitor may be coupled to the output of mixer 64.

Such a technique can further increase sensitivity. To provide adequate time resolution and avoid drift in DC conditions of the detector circuitry, a pulse rate of a few hertz to a few tens of kilohertz, for example, 100Hz, can be advantageously employed.

If the second harmonic reflection from the tag is modulated by a "tone" (in this case, any frequency up to a few megahertz) or data, further circuitry can be used to provide increased discrimination and/or additional information from the tag. If a modulating tone is provided, the bandwidth of low pass filter 68 should be chosen to pass this frequency. If greater selectivity is required a band pass filter centred at the tone frequency could be used instead of or in addition to low pass filter 68, to provide additional noise rejection. The improvement will be the ratio of the band pass filter to low pass filter bandwidths. Alternatively, other conventional tone detection circuitry can be employed. Similarly data from the tag can be additionally filtered and recovered and made available by conventional means.

The homodyne radar can operate at almost any frequency and the operating frequency can be chosen to comply with, for example, regulatory restrictions and to avoid interference from mobile telephones.

The transmit and receive antennas of the homodyne radar described above can be physically mounted adjacent to or separate from one another. For example, a gate could comprise a pair of transmit and receive antennas located together in a single RF transparent or translucent enclosure such as a pillar or a ceiling-mounted unit, to

protect a space such as an open shop-front. A single stand-alone "gate" can provide omnidirectional coverage by using vertically mounted transmit and receive dipole antennas. The sensitivity of tag detection enhances the practicality of this configuration. The ability of the tagging system to operate at high frequencies also allows the use of relatively directional antennas.

Figure 5 shows one form of a gateway which has two opposing gates and which can be used with the tags and radar described above. The more sensitive detection system of the present invention allows a greater width between supports 100 than can easily be provided by conventional systems. For example, a 2 metre gate separation 106 is readily achievable. One of the gates carries at least an RF antenna; the other carries either a second antenna or an RF reflector; both gates may each carry an RF transmit and an RF receive antenna. Two "stand-alone" gates, each with both a transmit and receive antenna provides a gate width of twice the detection range of a stand-alone gate. However, the use of a pair of gates, one carrying only a transmit antenna, the other only a receive antenna, can also effectively double the range which would otherwise be achieved if co-located transmit and receive antennas were used. Alternatively one gate can carry transmit and receive antennas and the other gate can be provided with RF reflector to concentrate the RF field between the gates. When operating at high frequencies directional antennas such as patch antennas or preferably patch antenna (phased) arrays can be used for the transmitting antenna 102 and receiving antenna 104. Advantageously, a patch antenna has a PTFE or similar substrate, the other side of which carries antenna driver circuitry. Patch antennas

have advantages including low manufacturing cost, a flat physical profile and a smaller size than wire loop antennas. Furthermore, there will be very little radiation or sensitivity behind the patch antennas, which, combined with the directional nature especially pronounced in an array results in a clearly defined sensitive region between the gates. The well- defined nature of this detection region makes it practicable to use much wider gate separations if required. For example, pairs of gates could be situated in the floor and ceiling or on either side of an open shop front to cover the entire open frontage with a narrow well-defined detection plane.

Since the return frequency from a tag is different from the illuminating frequency and since the polarisation of the incident and reflected radiation is not a primary consideration, the patch antennas may be "tuned" for enhanced selectivity. For example, a patch antenna with a rectangular metal patch will have two important resonances, one at a frequency determined by the length of the rectangle, the other at a frequency determined by the rectangle's width. Figure 6 shows a patch antenna 110 comprising a substrate 112 and a conductive patch 114. The conductive patch has a longitudinal axis 116 and a transverse axis 118 of a different length to the longitudinal axis.

Generally, any patch geometry (that is, the geometry of the electrically conductive patch region) with unequal longitudinal and transverse axes will provide enhanced selectivity; to select a second harmonic return the ratio of lengths should be approximately 1:2.

If required a tag can incorporate means for "neutralising" its activity. In one configuration, a region of the tag, normally part of a capacitor, is provided with opposing foil conductors separated by a narrow dielectric spacer. A high power RF field is applied to the immediate proximity of this region causing irreversible dielectric breakdown and providing a reduced resistance between the foil conductors which loads or shorts out the tuned circuit, or moves its resonant frequency out of the range of the detection system. Alternatively, as well as or instead of dielectric breakdown, the high power RF field can be used to couple sufficient energy into the tag to break down the semiconductor junction, for example by inducing a high voltage across the junction.

Many other effective alternative configurations will occur to those skilled in the art and it should be understood that the present invention is not limited to the illustrated embodiments.

CLAIMS

1. An electronic tag which when stimulated by radiation at a first frequency responds by producing radiation at a second frequency different from the first.

2. A tag as claimed in claim 1 wherein the radiation is radio frequency electromagnetic radiation.

3. A tag as claimed in claim 1 or claim 2 wherein the second frequency is an integer multiple of the first frequency.

4. A tag as claimed in claim 3 wherein the integer multiple is two.

5. A tag as claimed in any preceding claim comprising a non-linear element.

6. A tag as claimed in any preceding claim comprising a tuned circuit.

7. A tag as claimed in claim 6 wherein the tuned circuit is a lumped element.

8. A tag as claimed in claim 5, 6 or 7 wherein the non-linear element comprises a Schottky diode.

9. A tag as claimed in any one of claims 6 to 8 further comprising an oscillator to modulate the radiation at the second frequency.

10. A tag as claimed in any one of claims 6 to 9 further comprising means to provide data to modulate the radiation at the second frequency.

11. A tag as claimed in claim 9 or claim 10 wherein the radiation at the second frequency is modulated by changing the Q of the tuned circuit.

12. A tag as claimed in claim 11 further comprising chopping means to change the Q of the tuned circuit.

13. A tag as claimed in any preceding claim wherein the first frequency is less than 20MHz.

14. A tag as claimed in any one of claims 1 to 12 wherein the first frequency is greater than 100MHz.

15. A tag as claimed in any preceding claim wherein the tag is a passive tag.

16. A tag as claimed in any preceding claim having a substantially laminate physical form.

17. A tag substantially as hereinbefore described with reference to Figures 2 and 3.

18. A homodyne radar to detect an electronic tag comprising a non-linear element, the radar transmitting at a first frequency and responding to a signal received at a second frequency different to the first frequency.

19. A homodyne radar as claimed in claim 18 wherein the second frequency is an integer multiple of the first frequency.

20. A homodyne radar as claimed in claim 19 wherein the integer multiple is two.

21. A homodyne radar as claimed in claim 20 wherein an oscillator operating at the first frequency provides a transmit signal and wherein a second harmonic of the oscillator is mixed in a mixer with a received signal.

22. A homodyne radar as claimed in claim 21 wherein the mixer output is coupled to a low-pass filter, the low-pass filter output is coupled to means to remove d.c. bias, and the means to remove d.c. bias is coupled to means to detect an a.c. component of a signal and means to provide an output to indicate detection of a tag.

23. A tag detection gate including a patch antenna, the patch antenna having a conductive patch with longitudinal and transverse axes of different lengths.

24. A tag detection gate as claimed in claim 23 comprising transmit and receive patch antenna arrays.

25. A tag detection gateway comprising two opposing gates, one of which is a tag detection gate as claimed in claim 23 or 24, and the other of which comprises an RF antenna or RF reflector.

26. An electronic tagging system comprising:
an electronic tag; and,
a homodyne radar to detect the tag.

27. An electronic tagging system as claimed in claim 26 wherein the homodyne radar comprises:
a signal source at a first frequency coupled to a transmit antenna,
a receive antenna, and
a mixer coupled to the receive antenna and to a signal source at a second frequency and providing an output to a detection circuit;
the signal source at the second frequency providing a signal which is derived from or shares a common origin with the signal source at the first frequency.

28. An electronic tagging system as claimed in claim 27 wherein the homodyne radar further comprises a low-pass filter coupled to the output of the mixer.

29. An electronic tagging system as claimed in claim 28 wherein the homodyne radar further comprises means, coupled to the low-pass filter, to substantially remove a dc component from an output from the filter, and means to detect a remaining ac component.

30. An electronic tagging system as claimed in claim 28 or claim 29 wherein the low-pass filter has a bandwidth at least one hundred times less than the first frequency.

31. An electronic tagging system as claimed in any one of claims 26 to 30 wherein the homodyne radar further comprises means to vary the first frequency during tag detection.

32. An electronic tagging system as claimed in claim 31 wherein the variation comprises sweeping the first frequency over a range.

33. An electronic tagging system as claimed in any one of claims 27 to 32 wherein the homodyne radar has a pulsed transmitted output.

34. An electronic tagging system as claimed in claim 33 wherein the detection circuit operates synchronously with the pulsed transmitted output.

35. An electronic tagging system as claimed in any one of claims 27 to 34 wherein at least one of the transmit antenna and receive antenna is directional.

36. An electronic tagging system as claimed in claim 35 wherein at least one of the transmit antenna and receive antenna is a patch array.

37. An electronic tagging system as claimed in any one of claims 26 to 36 wherein the electronic tag comprises a non-linear element and wherein the first and second

frequencies are different.

38. A method for detecting an electronic tag comprising:
providing a tag including a non-linear element,
providing r.f. radiation at a first frequency to the tag, and
detecting r.f. radiation at a second frequency, different to the first, from the tag.

39. A method as claimed in claim 38 wherein the steps of providing and detecting r.f. radiation use a homodyne radar.

40. A method as claimed in claim 39 wherein the step of providing r.f. radiation comprises sweeping the first frequency over a range.

41. A method as claimed in claim 39 or claim 40 wherein the step of providing r.f. radiation comprises providing pulsed r.f. radiation.

42. A method as claimed in claim 41 wherein the step of detecting comprises synchronous detection of the r.f. radiation at the second frequency.

43. A method as claimed in any one of claims 38 to 42 wherein the non-linear element comprises a semiconductor junction and wherein the second frequency is an integer multiple of the first frequency.

44. A method as claimed in claim 43 wherein the integer multiple is two.

45. A method as claimed in any one of claims 38 to 44 wherein the tag is a passive tag.

specs/atc.spc

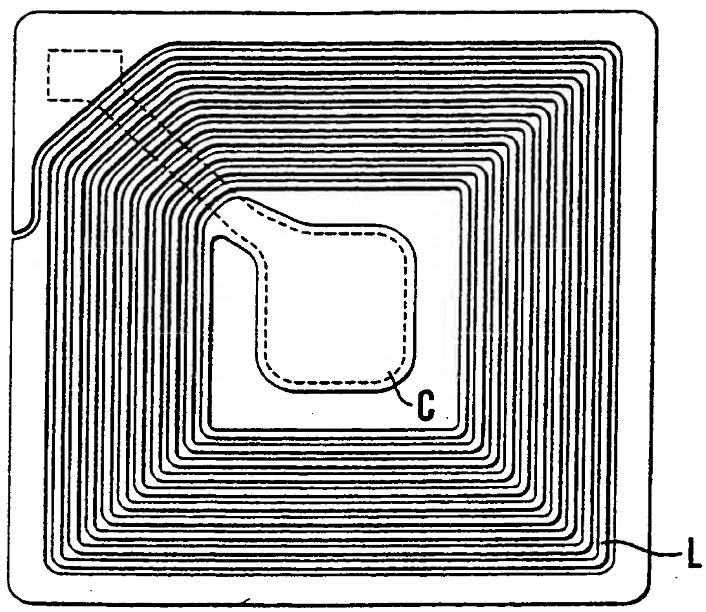


Fig. 1

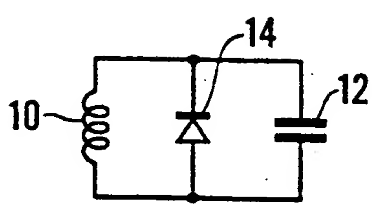


Fig.2a

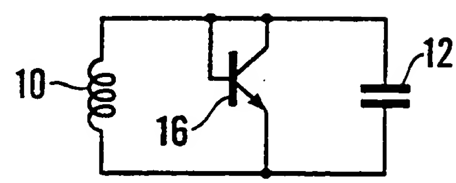


Fig.2c

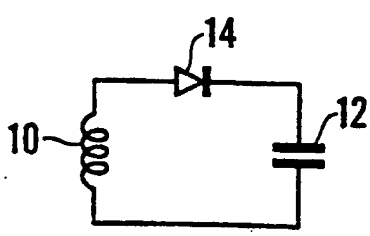


Fig.2b

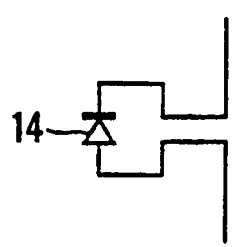


Fig.2d

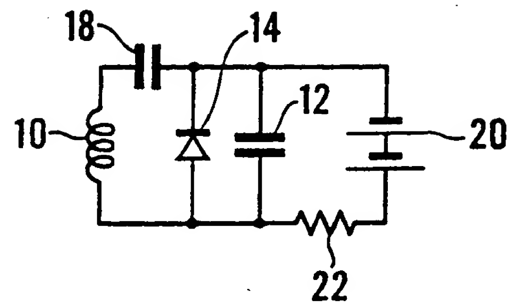


Fig.2e

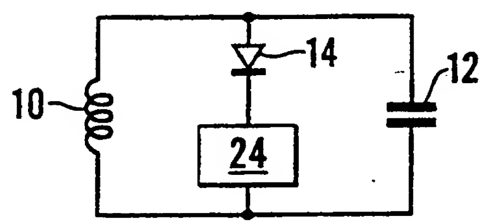


Fig.3a

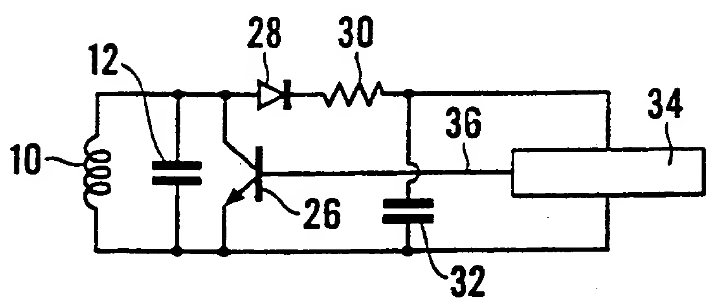


Fig.3b

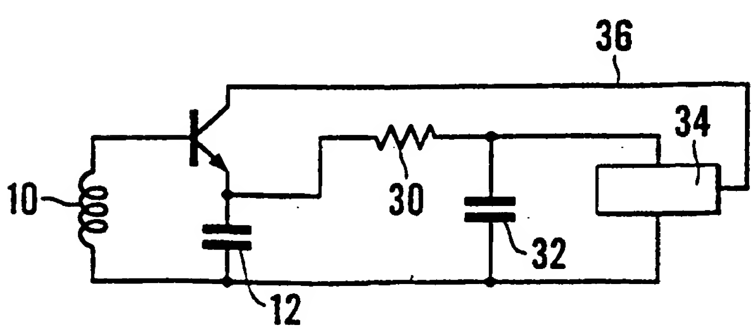


Fig.3c

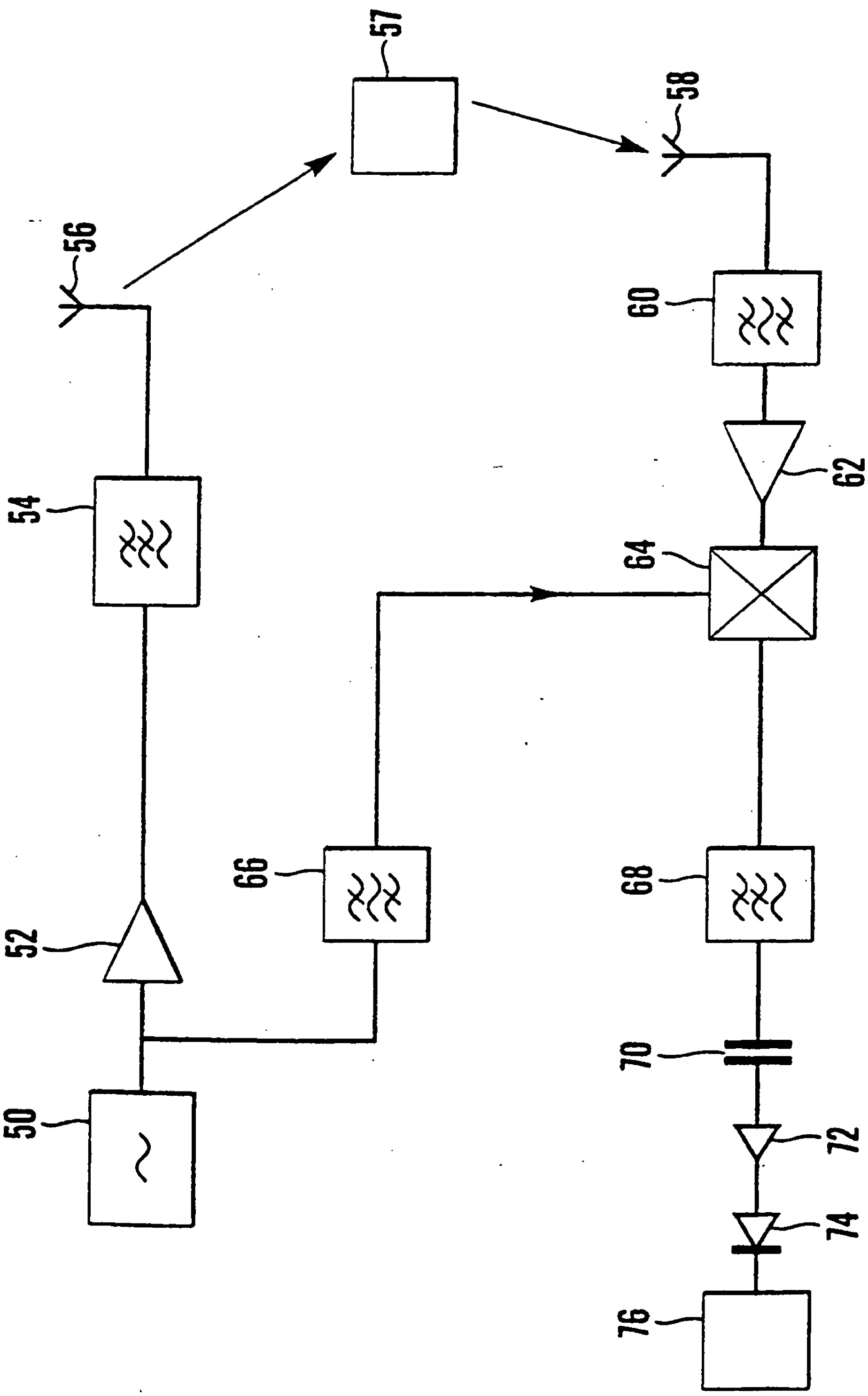


Fig.4

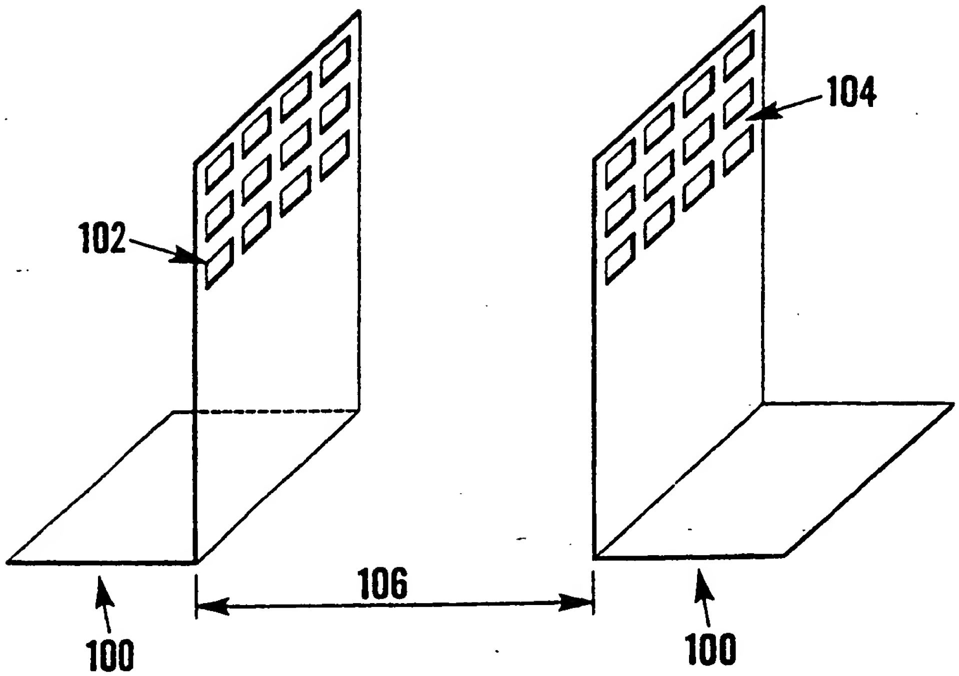


Fig.5

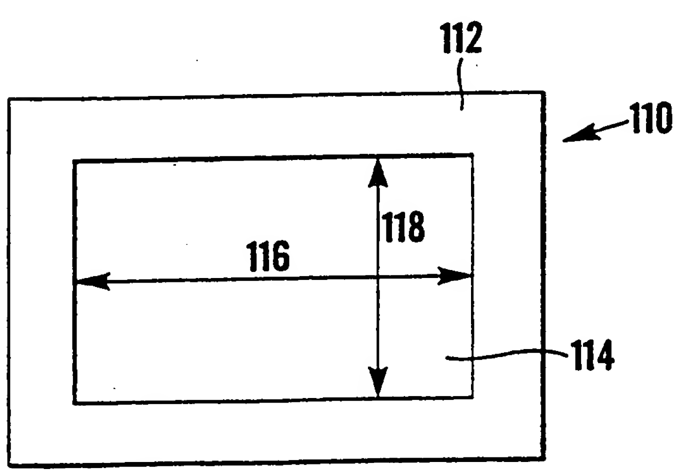


Fig.6

INTERNATIONAL SEARCH REPORT

Inte' onal Application No
PCT/GB 98/03848

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G06K7/08 G06K7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 914 762 A (KLENSCH RICHARD JOSEPH) 21 October 1975	1-10, 13-20, 23-27, 33,35, 37-39, 43-45
	see column 1, line 40-50	
Y	see column 3, line 33 - column 4, line 66; figures 1,11	11,12, 21,22, 28-30, 36,40-42
	see column 5, line 36-52 see column 12, line 45-56; claim 7 ---	
X	WO 97 05559 A (BRITISH TECH GROUP INT ;SCHEELEN JOS (BE)) 13 February 1997	1,2,15
Y	see page 1, line 10-17; figure 4A see page 4, line 19-26 ---	11,12
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 April 1999	14/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cardigos dos Reis, F

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 98/03848

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 710 853 A (INTEGRATED SILICON DESIGN PTY) 8 May 1996	1,2,15, 16
Y	see column 1, line 3-45	21,22, 28-30
	see column 12, line 41 - column 13, line 15 see column 16, line 21 - column 17, line 40; claim 33; figure 11 ---	
X	US 4 300 183 A (RICHARDSON ROBERT H) 10 November 1981	23-25
Y	see column 3, line 19-25; figures 9,11 see column 4, line 18-65 ---	36
X	US 4 725 841 A (NYSEN PAUL A ET AL) 16 February 1988	26,27, 31-34
Y	see abstract; figure 1 see column 10, line 67 - column 11, line 27 ---	40-42
X	US 3 713 102 A (MARTIN S) 23 January 1973	1,2,15, 16
A	see column 2, line 31-49; figure 2 see column 10, line 41-53 ---	7
X	US 5 523 749 A (COLE PETER H ET AL) 4 June 1996	1,2,15, 16
A	see abstract; figures 1,4B,10 see column 4, line 23-36 see column 10, line 66 - column 12, line 8 ---	9,18,26
X	WO 96 34299 A (BRITISH TECH GROUP INT ;SCHEELEN JOS (BE)) 31 October 1996 see page 1, line 15-28 see page 2, line 26 - page 3, line 2; figure 1 -----	26,27,31

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 98/03848

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3914762 A	21-10-1975	CA 1033040 A	13-06-1978
		CA 1040292 A	10-10-1978
		DE 2460280 A	10-07-1975
		DE 2462457 A	30-06-1977
		FR 2256416 A	25-07-1975
		GB 1488850 A	12-10-1977
		JP 50118695 A	17-09-1975
		NL 7416859 A	01-07-1975
WO 9705559 A	13-02-1997	AU 702723 B	04-03-1999
		AU 6627196 A	26-02-1997
		CA 2226897 A	13-02-1997
		CN 1192283 A	02-09-1998
		EP 0842484 A	20-05-1998
EP 0710853 A	08-05-1996	AT 140800 T	15-08-1996
		AU 645487 B	20-01-1994
		AU 5087990 A	05-09-1990
		WO 9009707 A	23-08-1990
		DE 69027922 D	29-08-1996
		DE 69027922 T	27-02-1997
		EP 0458821 A	04-12-1991
		JP 4505654 T	01-10-1992
US 4300183 A	10-11-1981	NONE	
US 4725841 A	16-02-1988	NONE	
US 3713102 A	23-01-1973	NONE	
US 5523749 A	04-06-1996	AU 664544 B	23-11-1995
		WO 9217866 A	15-10-1992
		EP 0578701 A	19-01-1994
		US 5793305 A	11-08-1998
WO 9634299 A	31-10-1996	AU 5505596 A	18-11-1996
		CA 2219229 A	31-10-1996
		EP 0823059 A	11-02-1998